Using Multi-Decadal Records of Long-Lived Constituents to Understand Dynamical Processes Affecting O_3 Trends

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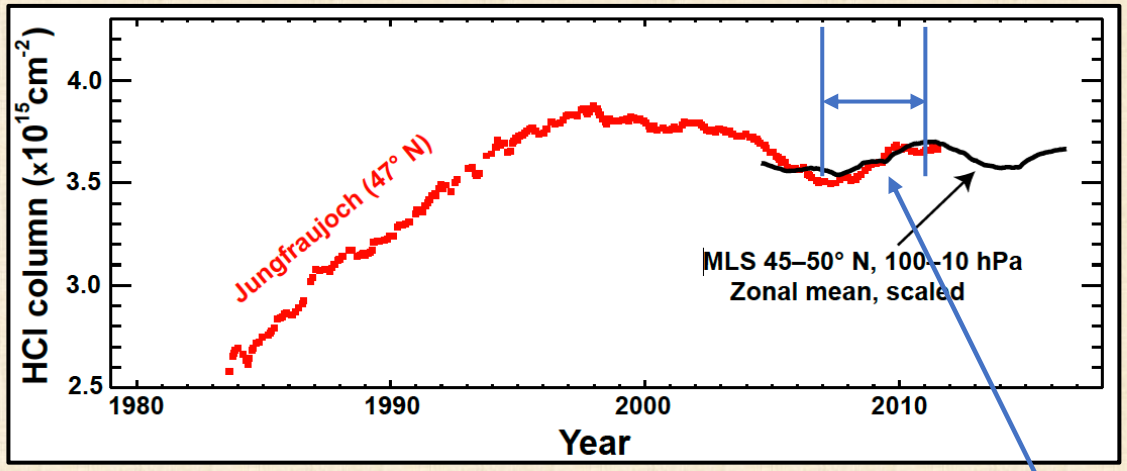
Circulation variability is apparent in observational records of constituents like HCl and N_2O



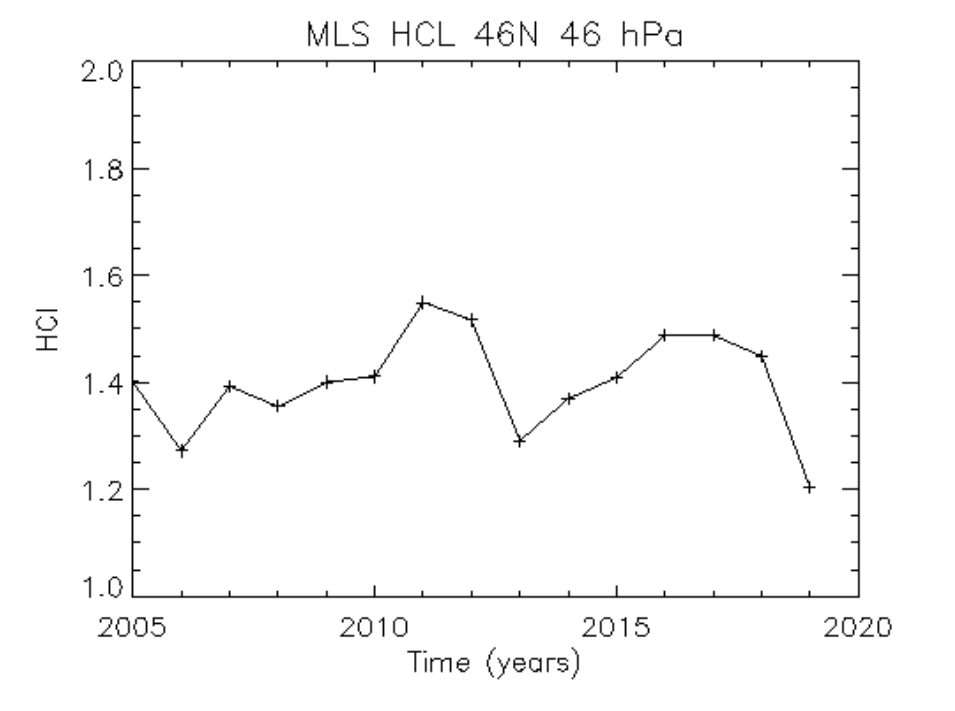
HCl column increases and decreases (NDACC,GOZCARDS Jungfraujoch) *Mahieu et al*., Nature, 2014) in spite of observed decrease in chlorine containing source gases at the surface.

Figure from *Stolarski et al*., Using satellite measurements of N_2O to remove dynamical variability from HCl measurements, *Atmos. Chem. Phys*., 2018

A 'Mahieu' event*

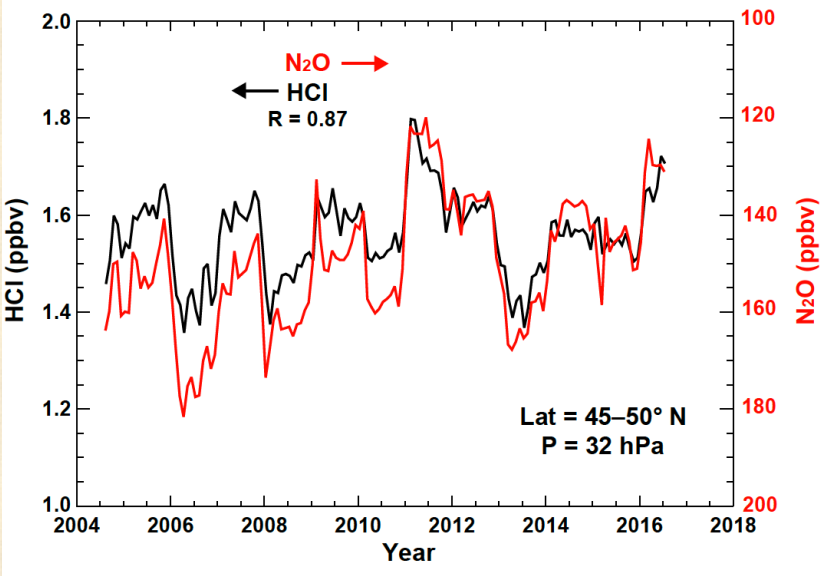
*'trends' (oscillations?) ~15%/decade (much larger than expected trend based on ground measurements of source gases)

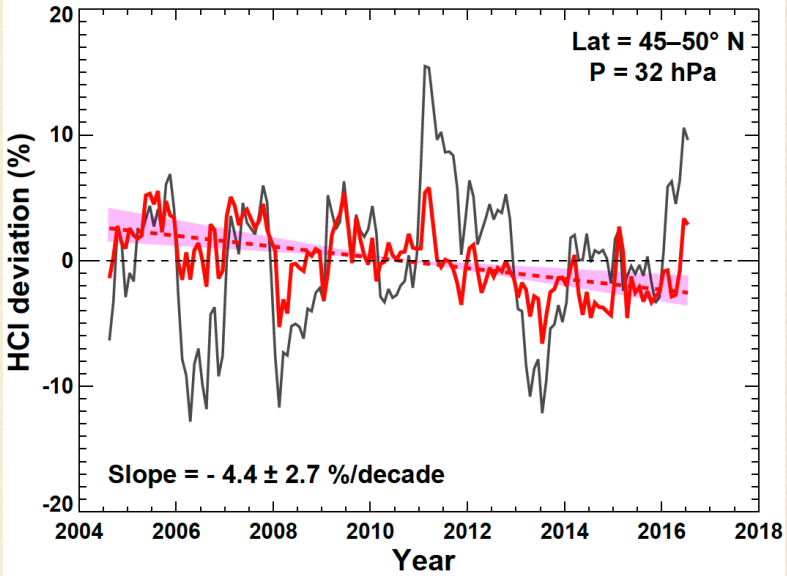
Apparently, ‘Mahieu events’ are common



April Monthly Zonal Average HCl

Circulation variability is apparent in observational records of constituents like HCl and N_2O



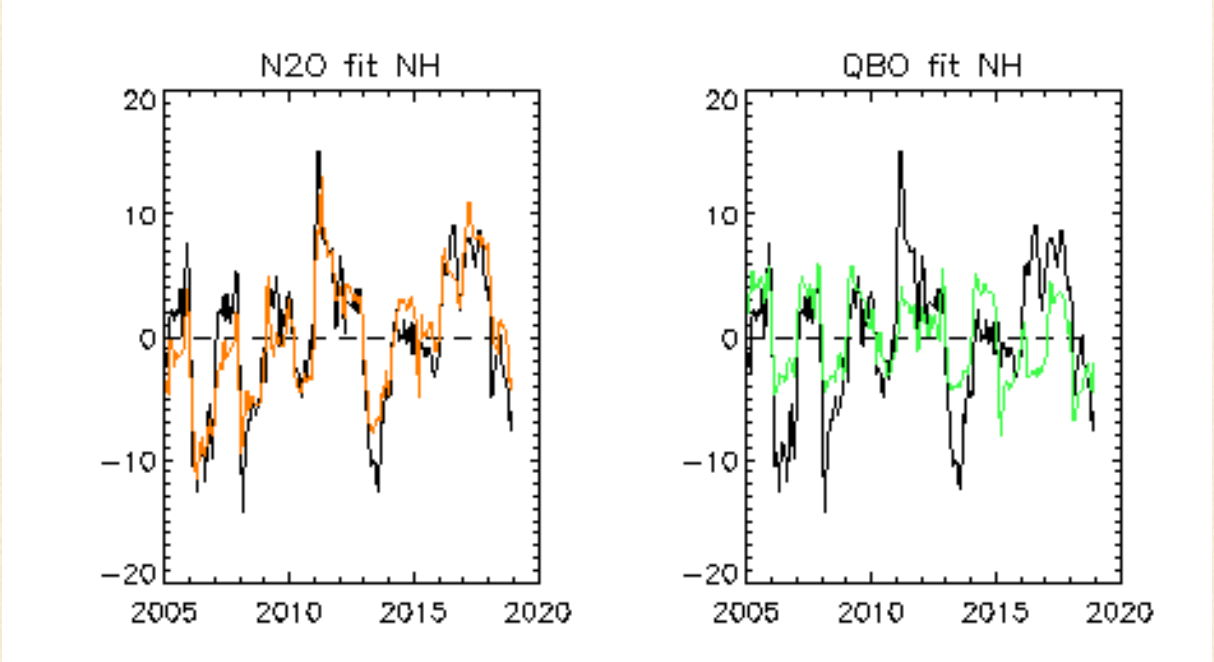


- (left) N_2O anomalies are strongly correlated with HCl anomalies
- (right) Statistically significant *negative HCl* trend obtained using N_2O to account for dynamic variability
- Results of 'normal' MLR (seasonality, QBO, ENSO, and a trend) are inconsistent with observed changes in tropospheric source gases.

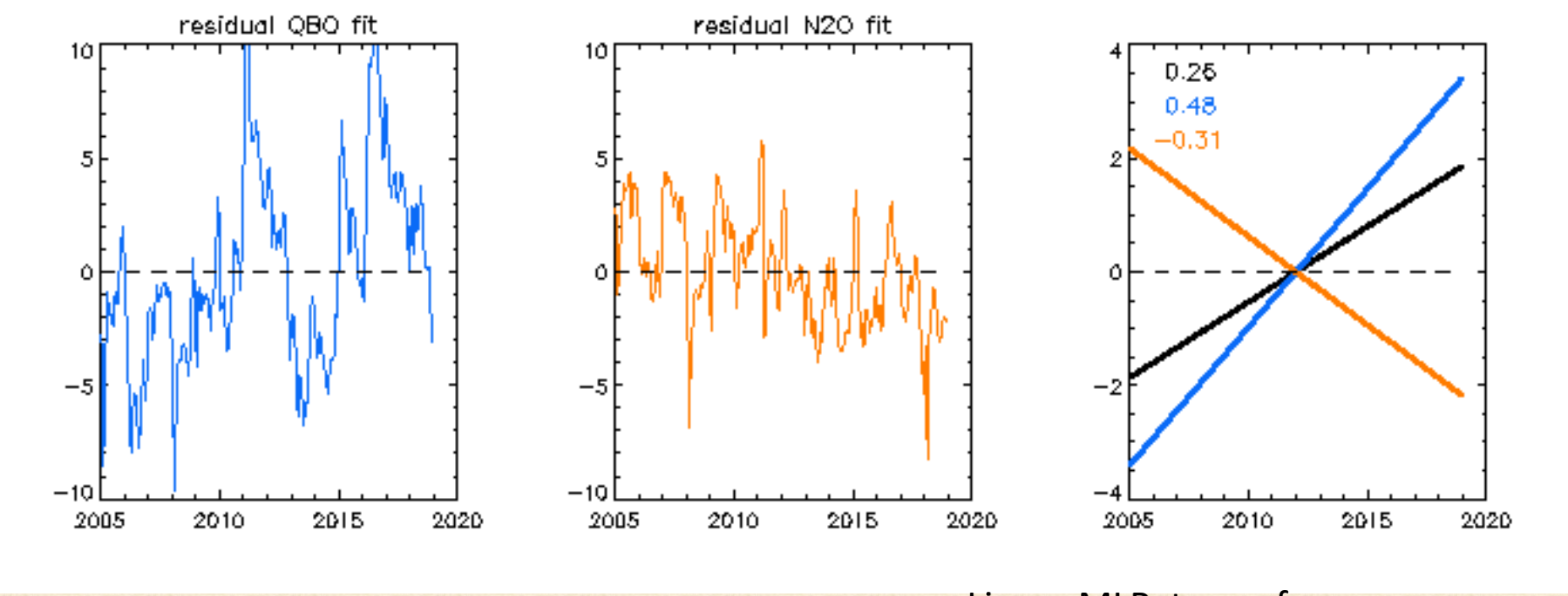
Compare standard MLR fit and fit using N_2O

Fits at 31.6 hPa

Y-axis is PERCENT



Compare residuals using
(a) QBO and seasonal terms (blue)
(b) N_2O and seasonal terms (orange)



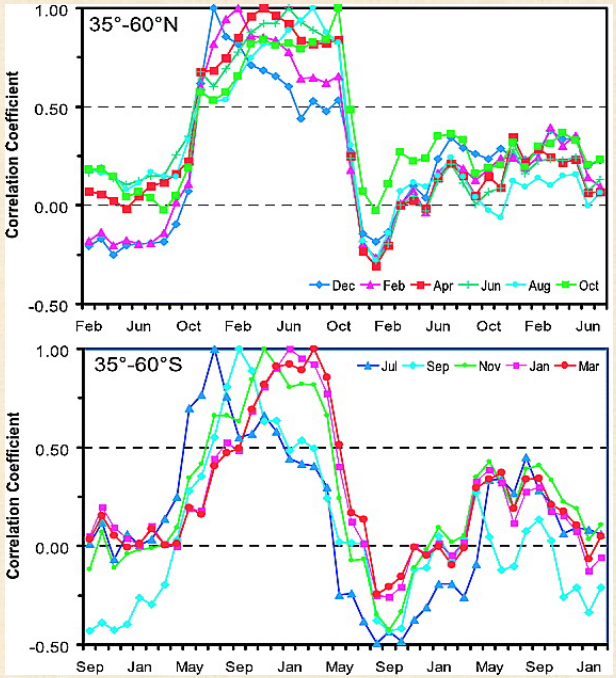
Linear MLR terms for

a) SEASONAL VARIABILITY ONLY (black)
b) QBO and seasonal (blue)
c) N_2O and seasonal (orange)

Switch gears and think about Some Other Things We Already Know (autocorrelation)

Northern Hemisphere

Southern Hemisphere

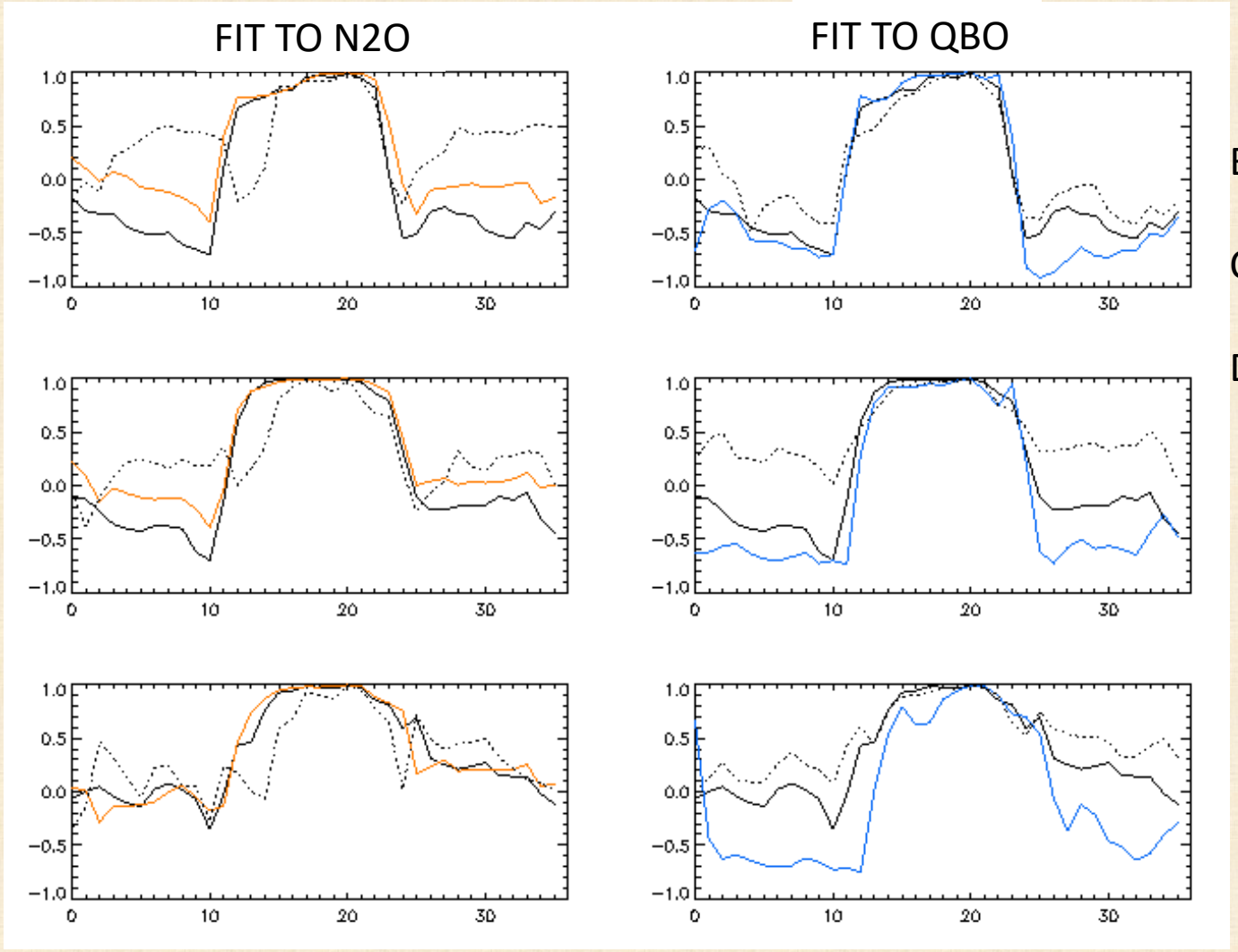


Fioletov and Shepherd, Seasonal persistence of midlatitude total ozone anomalies, GRL, 2003.

Total Colum Ozone autocorrelation (1979 - 2001)
Each color represents a different month of the year.

Autocorrelation – where chemistry is slow, anomalies accumulated over one winter PERSIST until set-up of the next winter circulation

Calculate Autocorrelation of the HCl DATA (BLACK), the FIT (COLORED), and the RESIDUAL (dashed)



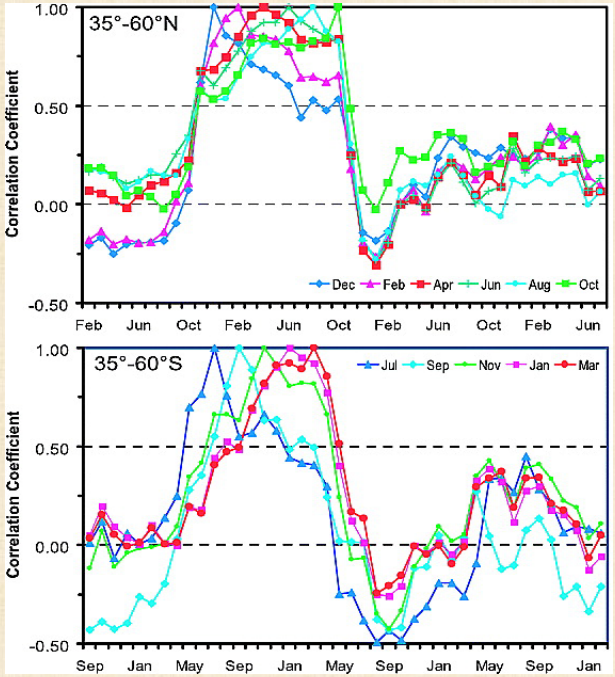
Black Solid Line: Data Autocorrelation

Colored Solid Line: Fit Autocorrelation

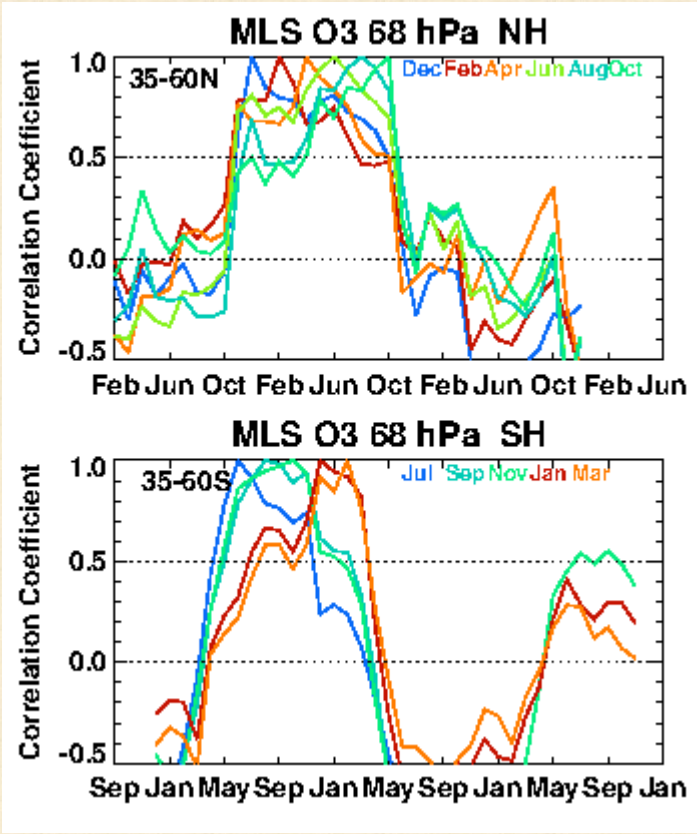
Dashed Line: Residual Autocorrelation

Lower Atmosphere – AUTOCORRELATION OF RESIDUAL looks more like that of DATA than AUTOCORRELATION OF QBO FIT

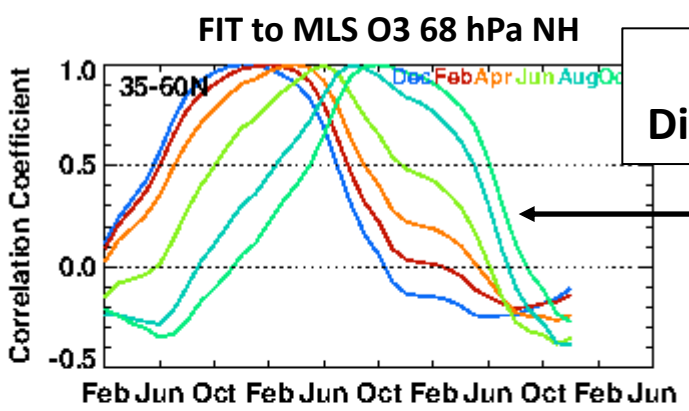
Relevance to Ozone Trends?



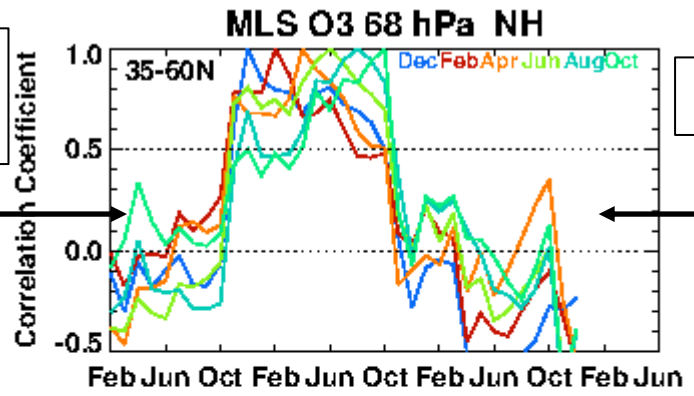
Total Colum Ozone autocorrelation (1979 - 2001) Each color represents a different month of the year.



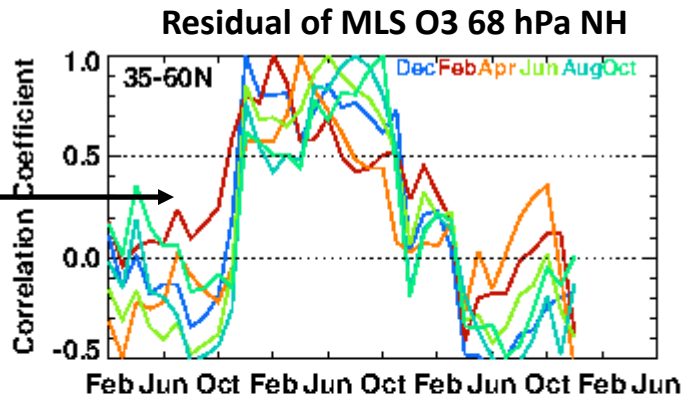
Autocorrelation of MLS O_3 at 68 hPa (2005 – 2017). Each color represents a different month of the year.

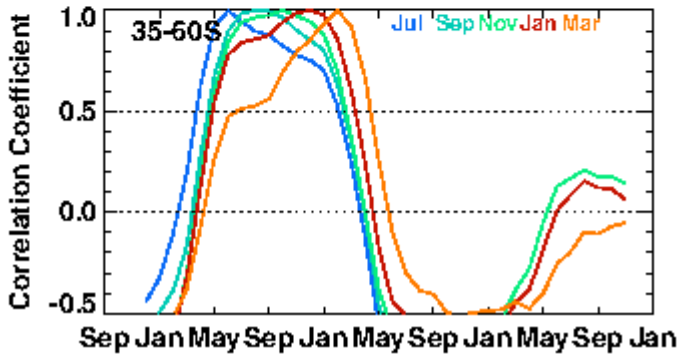


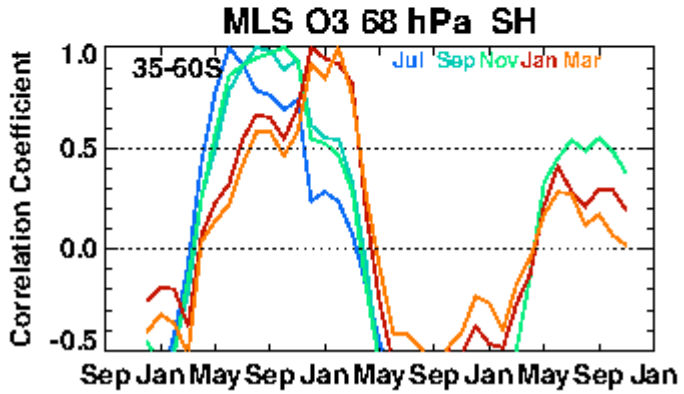
Very Different

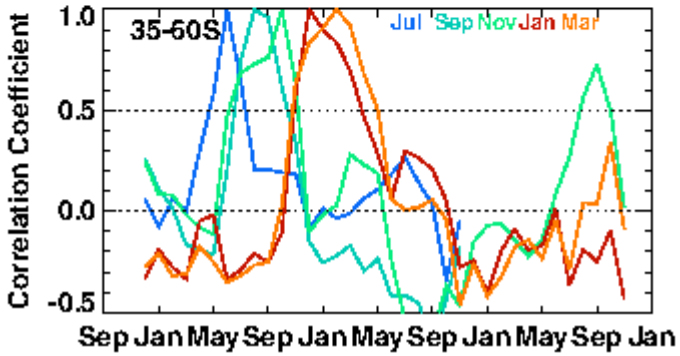


Similar









Autocorrelation of STANDARD QBO FIT to MLS timeseries

MLS Autocorrelation

Autocorrelation of RESIDUAL of FIT to MLS timeseries

Conclusions

- Species *Other than Ozone* show how dynamical variability can affect trends (important note: the expected HCl trend due to the Montreal Protocol is ~ 4x that expected for lower stratospheric ozone due to chlorine change)
- Multiple Linear Regression residuals are informative beyond their use in estimating errors and statistical significance in derived linear trends, i.e., the geophysical significance of a linear trend is greater if the MLR fit represents *persistence of anomalies* (i.e., captures the autocorrelation of the original timeseries).